• Investigation •

Prevalence of color vision deficiency among Chinese college students and their quality of life

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Abstract

● **AIM:** To investigate the prevalence of color vision deficiency (CVD) among college students and their quality of life (QoL) in a Chinese college.

● **METHODS:** This cross-sectional study was performed in Sichuan University in Chengdu, China. The questionnaire containing participants' demographic data, as well as CVD related QoL was distributed to students who were screened as CVD [by Color Vision Examination Plates (Version 6)] in 2022 freshman entrance examination. Color blindness QoL (CBQoL) and utility analysis were used to evaluate the QoL of CVD students.

● **RESULTS:** There were 381 of 17 303 (2.20%) students screened as CVD, including 368 (4.11%) males and 13 (0.16%) females. A total of 317 students completed the questionnaire, the response rate was 83.20%. Only 166 participants (52.3%) knew they have CVD before the physical examination for college entrance examination, while a total of 145 participants (45.74%) hoped to be diagnosed earlier. The medians of CBQoL score and utility were 5.85 (range 2.2-6) and 1 (range 0-1), respectively. The proportions of students whose QoL is affected by CVD were 67.63% (211/312) and 42.27% (134/317) measured by CBQoL and utility analysis respectively.

● **CONCLUSION:** The prevalence of CVD in males is much higher than that in females. The time when CVD students first became aware of their CVD is relatively late. The QoL of the study population is quite high, while a large proportion of students' QoL are affected by CVD. It is suggested that as a congenital defect, CVD screening in China should be earlier, and appropriate guidance and support are needed for CVD patients to help them better adapt to life, study, and work.

● **KEYWORDS:** color vision deficiency; prevalence; quality of life; utility analysis; college student

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INTRODUCTION

Color vision deficiency (CVD) is commonly called "color blindness" (CB), the majority of which is congenital red-green CVD. The prevalence of CVD in European Caucasians is about 8% in men and about 0.4% in women, and in Chinese and Japanese ethnicity 4%-6.5% in men and 0.2%-1.7% in women[1].

In CVD patients, three types of cone cells in the retina are partially missing or the proportion changes, resulting in the inability of CVD patients to distinguish some colors in the natural spectrum. People are exposed to a variety of colors in their life and work, and need to distinguish many different objects through color. CVD patients are supposed to encounter various difficulties in their lives[2-10], for example, CVD students faced more challenges when study science and art. They might make mistakes when they need to judge whether the fruit is ripe, whether the meat is cooked, and different kinds of drugs according to the color. Besides, it was difficult to distinguish traffic lights clearly when driving. For doctors, it might be hard to distinguish different color of rashes in their daily work. However, little was known for Chinese CVD patients. Are their lives affected by the CVD? Is there anything we can do to improve their quality of life (QoL)?

Surprisingly, the impact of CVD on QoL has not been considered as an important topic for a long time. So far, there is no recognized standard questionnaire or scale for testing the QoL of CVD patients. In recent years, Barry *et al*[11] created CBQoL to evaluate the QoL of CVD individuals from three aspects, health and lifestyle, emotions, as well as work, which

was thought to be comprehensive. While utility analysis is another simple and effective method to determine the overall impact of the disease on patients. In the present study, we analyzed the prevalence of CVD among college students in a Chinese college, other than that, CBQoL and utility analysis were performed to evaluate the QoL of CVD students.

SUBJECTS AND METHODS

Ethical Approval The study was approved by the Institutional Review Board of Wang Jiang Hospital of Sichuan University and followed the tenets of the Declaration of Helsinki. Verbal informed consent from participants was obtained before implementation.

We collected the data of color vision examination of physical examination for college freshmen of Sichuan University in 2022, in Chengdu. Color Vision Examination Plates (Version 6) by Yu Ziping was used to check the color vision of the students. This color vision test has been widely used for color vision screening in various types of physical examinations in China, for example, college entrance examination, freshmen enrollment examination, conscription examination, and driver examination. However, the method can only screen out whether they have color vision abnormalities or not, but cannot determine the degree and type of color vision abnormalities. The students were asked to read 10 pictures quickly at the speed of 5-10s each in bright natural light. If more than one picture is read incorrectly, the student will be recorded as CVD. The questionnaire contained participants' demographic data such as age, gender, academic status, and some questions about CVD, as well as questions related to CBQoL and utility analysis. Students with CVD were asked to fill in the questionnaire at the time of physical examination. While to ensure that more questionnaires can be collected, we sent messages to remind them to complete the questionnaire after the physical examination. The questionnaire was created, published, and collected through Wen-juan-xing (www.wjx.cn), a professional online questionnaire, assessment, and voting platform.

The internal consistency of CBQoL was good with a Cronbach's α reliability up to 0.979[11]. The CBQoL questionnaire included 11 items about health and lifestyle aspect (for example, not noticing change in color of skin due to sunburn), 9 items about emotions (for instance, feeling anxious because of issues caused by problems seeing colors) and 3 items about work (for example, being limited in choice of work or career). Responses of CBQoL were on a 6-point Likert scale from 1= a severe problem, to 6=no problem, with an option for "not applicable". The average score was calculated, and the questions not answered were not included in the total number of questions. At the same time, we could calculate the average scores of different subscales (health and lifestyle, emotions, work).

Utility analysis is a preference-based measurement used to assess the QoL of patients in a given health state. It can measure how much the disease affects the patient's daily activities. A utility close to 1.0 indicates a high QoL in a given health state including capacities for physical activities as well as social and psychological health, and conversely, a utility close to 0 indicates a very poor QoL[12]. Two questions about time trade-off (TTO) utility analysis were also included in the questionnaire. The first question was "how many years of remaining life you think you have". The second question was "how many years of your remaining life you are willing to exchange if the exchanging can make your color vision return to normal". TTO utility analysis was selected to calculate the utility with the formula: Utility=1-(maximum time traded/ estimated remaining time of life).

Data analysis was performed on SPSS for Windows, version 25.0; IBM-SPSS, Chicago, IL, USA. Because the age, utility and QoL scores of our participants did not conform to normal distribution, we used the median, range and 25%-75% range to describe the trends of these continuous variables. When comparing continuous variables, we used Mann-Whitney *U* test (two independent samples) and Kruskal-Wallis *H* test (multiple independent samples). We used Spearman correlation analysis to analyze the correlations between two continuous variables. Pearson Chi-square tests were used to assess categorical variables. Multiple linear regressions were used to find the influencing factors of utility and QoL scores. All *P* values were two-sided and were considered statistically significant when <0.05.

RESULTS

Prevalence of Color Vision Deficiency A total of 17 303 students participated in the physical examination for freshmen, of which 381 (2.20%) students were screened as CVD, including 368 (4.11%) males and 13 (0.16%) females. The prevalence of CVD between males and females were significantly different (χ^2=313.93, P<0.001), as well as it between undergraduate (2.54%) and postgraduate (1.85%) (χ^2=9.60, P=0.002), as shown in Table 1.

Characteristics of the Participants A total of 317 questionnaires were collected, with a questionnaire response rate of 83.20%, including 308 males and 9 females. As shown in Table 2, the median age was 20 (range 17-38) years old. Only 23 (7.26%) students were screened as CVD for the first time. A total of 166 (52.3%) participants knew they have CVD before the physical examination for college entrance examination. Only 13 (4.1%) students did not want to know about their CVD earlier, while a number of 145 (45.74%) students hoped to be diagnosed earlier. Of 145 participants who wanted to be diagnosed

Table 1 The prevalence of CVD

Items	Students participated physical examination for freshmen (%)	Students with CVD (%)	Students completed the questionnaire (%)	Prevalence of CVD (%)	χ^2	*P*
Total	17303	381	317	2.20	313.93	<0.001
Male	8951 (51.73)	368 (96.59)	308 (97.16)	4.11		
Female	8352 (48.27)	13 (3.41)	9 (2.84)	0.16		
Undergraduate	8861 (51.21)	225 (59.06)	164 (51.74)	2.54	9.60	0.002
Postgraduate	8442 (48.79)	156 (40.94)	153 (48.26)	1.85		

CVD: Color vision deficiency.

Table 2 Utility and CBQoL score of CVD students

Items	Median	Range	25%-75% range	Mean rank	*H* (Kruskal-Wallis test)	*P*	QoL affected (%)
Age (y) (*n*=317)	20	17-38	18-23				
Utility (*n*=317)	1	0-1	0.982-1				134 (42.27)
CBQoL (*n*=312)	5.85	2.2-6	5.381-6				211 (67.63)
Subscale					22.267	<0.001	
CBQoL health and lifestyle (*n*=304)	6	1-6	5.628-6	510.08			126 (41.45)
CBQoL emotions (*n*=306)	5.889	1-6	5.333-6	449.81			160 (52.29)
CBQoL work (*n*=307)	5.667	1-6	5-6	417.58			157 (51.14)

CB: Color blind; QoL: Quality of life; CVD: Color vision deficiency.

earlier, 62 (42.76%) hoped to be aware of their CVD before primary school, 29 (20.00%) during primary school, 23 (15.86%) during junior high school, 31 (21.38%) during senior high school. Other demographic data of CVD students who completed the questionnaire were summarized in Tables 3 and 4.

QoL of Students with Color Vision Deficiency Table 2 showed the median of utility and CBQoL score were 1 (range 0-1) and 5.85 (range 2.2-6) respectively. The median scores of each subscale were 6 (CBQoL health and lifestyle), 5.889 (CBQoL emotions) and 5.667 (CBQoL work), the difference was statistically significant (H=22.267, P<0.001). Spearman correlation analyses found no relationship between utility and CBQoL score as well as three subscales (data not shown, P≥0.05). Proportion of students whose QoL was affected by CVD was 67.63% (211/312) for CBQoL and 42.27% (134/317) for utility analysis, as shown in Table 2.

Influencing Factors for the QoL of Students with Color Vision Deficiency By univariate analyses, we found age (r_s=0.215, P<0.001) and academic status (H=10.174, P=0.017) were influencing factors for utility. Students who were older and with the higher academic status had higher utility. While through multiple linear regression analysis, utility was not affected by any factor in our study.

Univariate analyses showed students who knew their CVD for the first time in this physical examination (U=2298.50, P=0.012 for CBQoL scores; U=2045.50, P=0.019 for CBQoL health and lifestyle scores; U=2148.50, P=0.004 for CBQoL work scores) and students whose driving test was not affected by their CVD (U=2849.500, P=0.023 for CBQoL scores; U=2723.500, P=0.009 for CBQoL health and lifestyle scores; U=2553.500, P=0.007 for CBQoL work scores) had significantly higher CBQoL scores, as well as higher scores for CBQoL health and lifestyle subscale and CBQoL work subscale. In addition, age was related to the score of CBQoL work subscale (r_s=0.161, P=0.005). All the factors in our study did not affect the score of CBQoL emotions subscale by univariate analyses. While after multiple linear regression analyses, students who knew their CVD for the first time (B=-0.386, P=0.029 for CBQoL scores; B=-0.660, P=0.009 for CBQoL work scores) and students whose driving test was not affected by their CVD (B=0.491, P=0.001 for CBQoL scores; B=0.634, P<0.001 for CBQoL health and lifestyle scores; B=0.774, P<0.001 for CBQoL work scores) still had significantly higher scores for CBQoL and some subscales. Other than that, students who did not hope to knew their CVD earlier had higher CBQoL scores (B=0.133, P=0.001) and CBQoL emotions scores (B=0.178, P=0.001).

DISCUSSION

To the best of our knowledge, this is the first study to investigate the prevalence and QoL of CVD in Chinese college students in Sichuan Province. In our study, the prevalence of CVD was 2.20% in total, 4.11% for males and 0.16% for females. Only half (52.3%) of the participants knew they have CVD before the physical examination for college entrance examination, while nearly half (45.74%) of the CVD students hoped to be diagnosed earlier. The utility and CBQoL scores in our study population were quite high. While there was still a large proportion of students whose QoL was affected by CVD. Among them, the score of CBQoL work subscale was

Table 3 Demographic data and influencing factors of CVD students

Demographic data	*n* (%)
Gender	
Male	308 (97.16)
Female	9 (2.84)
Academic status	
Undergraduate	164 (51.17)
Postgraduate (master degree)	117 (36.91)
Postgraduate (doctor degree)	36 (11.36)
Find out CVD for the first time?	
Yes	23 (7.26)
No	294 (92.74)
First time to find out you have CVD	
Before primary school	6 (1.89)
During primary school	34(10.73)
During junior high school	64 (20.19)
During senior high school (physical examination for college entrance examination not included)	62 (19.56)
Physical examination for college entrance examination	113 (35.65)
During and after college	27 (8.52)
NA	11 (3.47)
Hope to find out CVD earlier?	
Yes	145 (45.74)
No	13 (4.1)
Does not matter	159 (50.16)
When do you want to find out CVD (*n*=145)	
Before primary school	62 (42.76)
During primary school	29 (20.00)
During junior high school	23 (15.86)
During senior high school	31 (21.38)
Driving test affected by CVD?	
Yes	28 (8.83)
No	289 (91.17)

CB: Color blind; QoL: Quality of life; CVD: Color vision deficiency; NA: Not avaliable.

Table 4 Influencing factors of QoL of CVD students

Items	CBQoL		CBQoL health and lifestyle		CBQoL emotions		CBQoL work	
	B	*P*	*B*	*P*	*B*	*P*	*B*	*P*
Find out CVD for the first time?	-0.386	0.029					-0.660	0.009
Hope to find out CVD earlier?	0.133	0.001			0.178	0.001		
Driving test affected by CVD?	0.491	0.001	0.634	<0.001			0.774	<0.001
Adjusted R^2	0.071		0.074		0.037		0.090	

CB: Color blind; QoL: Quality of life; CVD: Color vision deficiency.

the lowest. The utility of CVD students was not related to the score of CBQoL as well as three subscales, and by multiple linear regression analysis, it was not affected by any other factor in our study. While students who knew their CVD for the first time, students whose driving test was not affected by their CVD and students who did not hope to knew their CVD earlier had higher CBQoL and/or subscale scores.

The prevalence of CVD in the present study was similar to a previous study in India (3.89% for males and 0.18% for females)[13]. Besides, the prevalence of CVD in males in our study (4.11%) was consistent with a previous study in Chengdu, China (5%)[14]. While the prevalence of female CVD in the study (0.16%) was much lower than the previous study (0.7%)[14]. One possible reason for that was our CVD screening method was relatively simple and the workload was pretty large, which made CVD students easy to escape diagnosis. While the number of women suffering from CVD was relatively small, once a little number of female CVD

escaped the diagnosis, the overall prevalence rate for female would be greatly affected. The CVD prevalence between undergraduate (2.54%) and postgraduate (1.85%) in our study was significantly different. The results of the impact of CVD on academic performance form previous studies were inconsistent[6,15-18]. Some studies found that there was no significant difference between CVD students and normal students in academic performance. While a previous study in British showed though the difference was not significant, people with CVD were less likely to receive higher education (68.9% *vs* 79.9%)[4]. Because there is a certain dependence on color in the process of education, we have reason to believe that when discussing CVD individuals, there would be obstacles in their learning process more or less.

In China, all entrance examinations conducted before the college entrance examination do not include color vision examination, while some majors in universities have restrictions for students with CVD, for example, medicine, public security technology, chemical engineering, agriculture and forestry, art, astronomy. In our study, only half of the CVD participants were aware of their CVD before the physical examination for college entrance examination. It meant that nearly half of the CVD students did not have enough time to choose or adjust their direction or interest of major before college, if their aspirations were just limited by CVD. While nearly 50% of CVD patients in a previous study were aware of their CVD in primary school[19]. It suggested that CVD screening in China is quite late.

The QoL of CVD students in the present study was quite good, whether measured by CBQoL or by utility. However, we found that there were a considerable number of students whose QoL were still affected by CVD, especially measured by CBQoL (67.63%). This meant that though CVD had little impact on the QoL of our study population, the scope of the impact may be extensive, in another word, because color exists in all aspects of our lives, CVD might have some impact on patients more or less during the whole life. Among them, CVD's greatest influence on students' QoL was reflected in work. In a study conducted in India, the subscale scores for CVD participants were 2.29 for emotion, 2.39 for health and 2.21 for work[20], much lower than that in our study (median 5.889, 6, 5.667 respectively). The difference may be due to the different age of the different study populations and different social environments. The age of the Indian study population was 29.09 years old, while participants in our study were quite young (20 years old). Our study showed age was related to the score of CBQoL work subscale by univariate analysis. Another possible explanation for the difference was that the severity of CVD may be different in two different study populations, which would have a great impact on the QoL.

In our study, students who knew their CVD for the first time, students whose driving test was not affected by their CVD and students who did not hope to knew their CVD earlier had higher CBQoL scores or subscale scores. The reason for this result was not clear and was difficult to explain, but it might have something to do with the design flaw of our study. Color vision screening methods in our study (Color Vision Examination Plates by Yu Ziping) was too simple to determine the degree and type of CVD, which is an important confounding factor that may have a great impact on the QoL of CVD patients. We believed that students with more severe CVD might not easy to pass the driver's license test and was supposed to be aware of their CVD earlier, as well as with a worse QoL, in another word, all of these were the results of severe CVD.

Consistent with our results, some studies[20-22] showed that CVD had little impact on patients' life, study, work, driving and other aspects, so a number of researchers suggested not to include color vision examination in the routine physical examination or entrance physical examination[4,16,22]. However some studies showed CVD did have an impact on some professions, such as police officer[23], doctor[24-25]. Proper guidance and some auxiliary equipment[6,26-28] may help them better adapt to daily life, study and work, for example, wearing colored lenses[29], choosing a subspecialty which is not limited by VCD, modifying the classic traffic lights for CVD patients[30]. Education workers and health workers should be educated about CVD. Other than that, we suggest that as a congenital defect, CVD screening in China should be earlier, in our opinion, physical examination at primary school entrance may be appropriate. At this time, children can generally accomplish the color vision examination, and CVD may not have had a great impact on their life and learning so far. In our view, parents and teachers should be aware of the CVD screening results but not the children themselves. Early detection of CVD may enable parents as well as teachers to be prepared, and learn how to correctly understand CVD, and how to help CVD children correctly deal with the problems caused by CVD in life and study. It depends on the parents and teachers to decide when to tell children that they have CVD, and how to guide children to correctly understand CVD and their possible impacts on the entire life. Besides, parents and teachers should pay attention to the emotional changes that may be caused by CVD on children and provide appropriate guidance.

Several limitations must be considered in interpreting our findings. First of all, as mentioned before, color vision screening methods in the present study was too simple to determine the degree and type of CVD, which had a pretty great impact on interpreting our results of QoL, especially

on the influencing factors of the QoL; Second, the CBQoL questionnaire used in our study was translated and proofread by two ophthalmologists from English to Chinese, and we did not conduct a large-scale pre-survey to test the Chinese version; Last but not the least, though the questionnaire response rate in our study was 83.20%, some students didn't fill in the questionnaire and the reasons were unknown, we had no idea whether these students were more affected by CVD or not, which resulted in selective bias.

In conclusion, in our study, the prevalence of CB in males was much higher than that in females. Only half of the participants knew they have CVD before the physical examination for college entrance examination. The utility and CBQoL scores in our study population were quite high, while a large proportion of students' QoL were affected by CVD. We suggest that as a congenital defect, CVD screening in China should be earlier, and appropriate guidance and support are needed for CVD patients to help them better adapt to life, study and work.

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